Electron Cloud Results from ILCDR08

Bob Zwaska

ECWG Meeting

July 22, 2008

ILCDR08

ILC Damping Rings R&D Workshop

And

CesrTA Kickoff Workshop

Talks available at:
https://wiki.lepp.cornell.edu/ilc/bin/view/Public/DampingRings/ILCDR08/

- About 40 people, mostly for ECloud
  - Some for low-emittance tuning
- Few interesting experimental techniques
- Simulation Plans
- Differences between electrons/positrons/protons

Introduction to the CesrTA Program
ILCDR08 – July 8, 2008

Mark Palmer & David Rubin

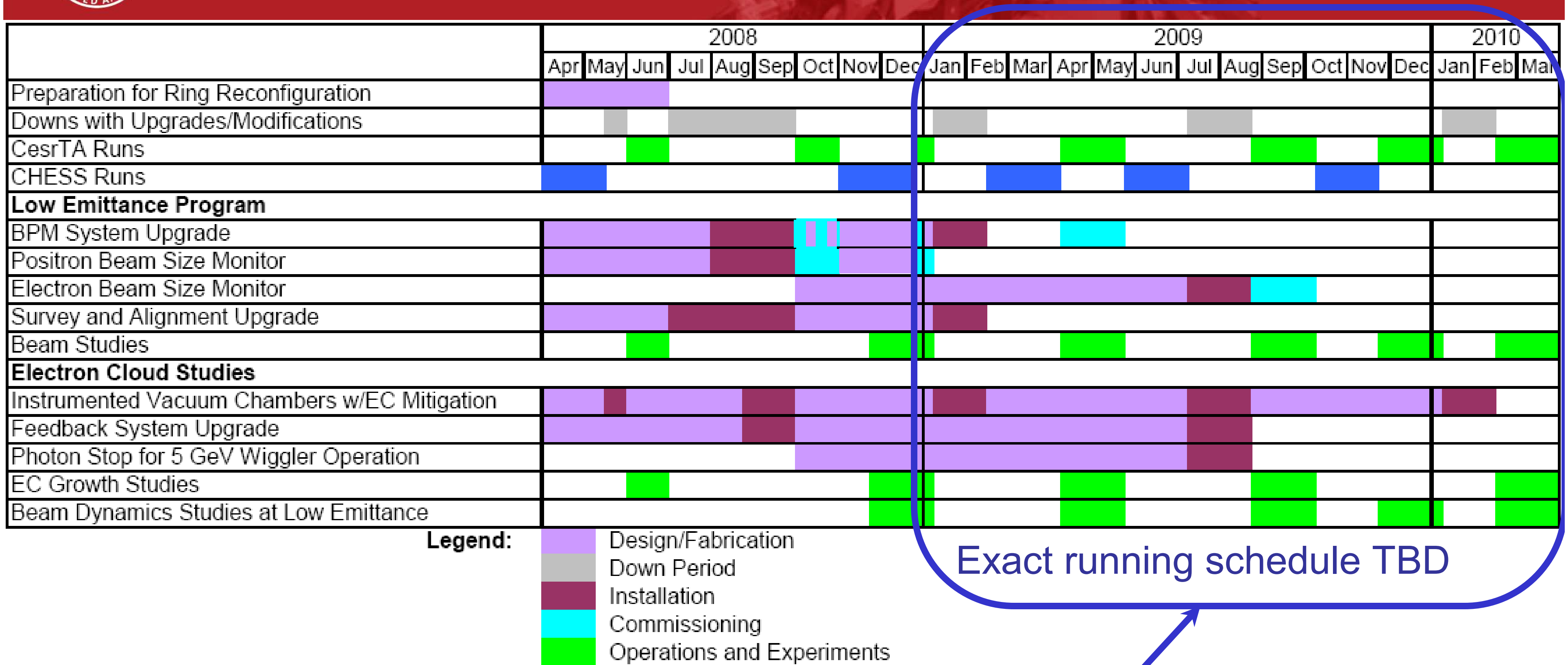
Cornell Laboratory for

Accelerator-Based Sciences and Education

De-Scoped CesrTA Program

- Plan continues to emphasize
  - EC Growth and Instability Studies [G. Dugan Talk this afternoon]
  - Development of low emittance tuning techniques (target $\varepsilon_y < 20$pm) [D. Rubin talk this afternoon]
  - Development of x-ray beam size monitor to characterize ultra low emittance beams (1-D camera array) [J. Alexander/J. Flanagan talks during working group sessions]
  - Program to preserve a total of ~240 CesrTA operating days
- De-scoped items
  - Study of ion related instabilities and emittance dilution
  - 2-dimensional x-ray beam size camera upgrade
  - Contingency for:
    - Follow-up tests of alternative mitigation techniques
    - Tests of ILC prototype hardware
    - Further reductions in beam emittance, and further refinement of low emittance tuning methodology

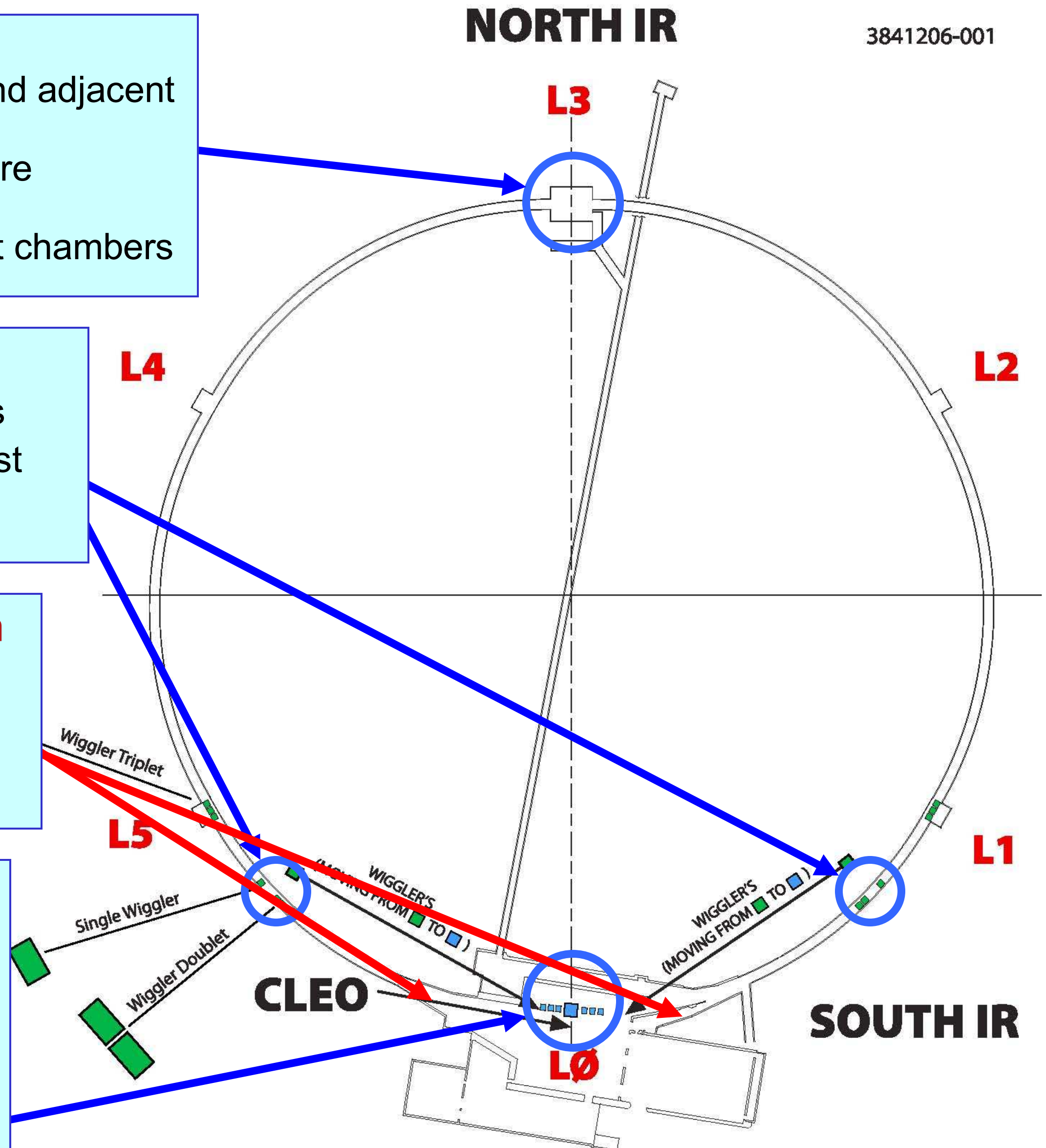
Schedule Overview



- Planned schedule as of early this year
  - Phased implementation of instrumentation
  - Phased installation of electron cloud diagnostics and support hardware
- Some adjustments are being made
  - Avoid holiday running
  - Maximize efficient use of limited resources

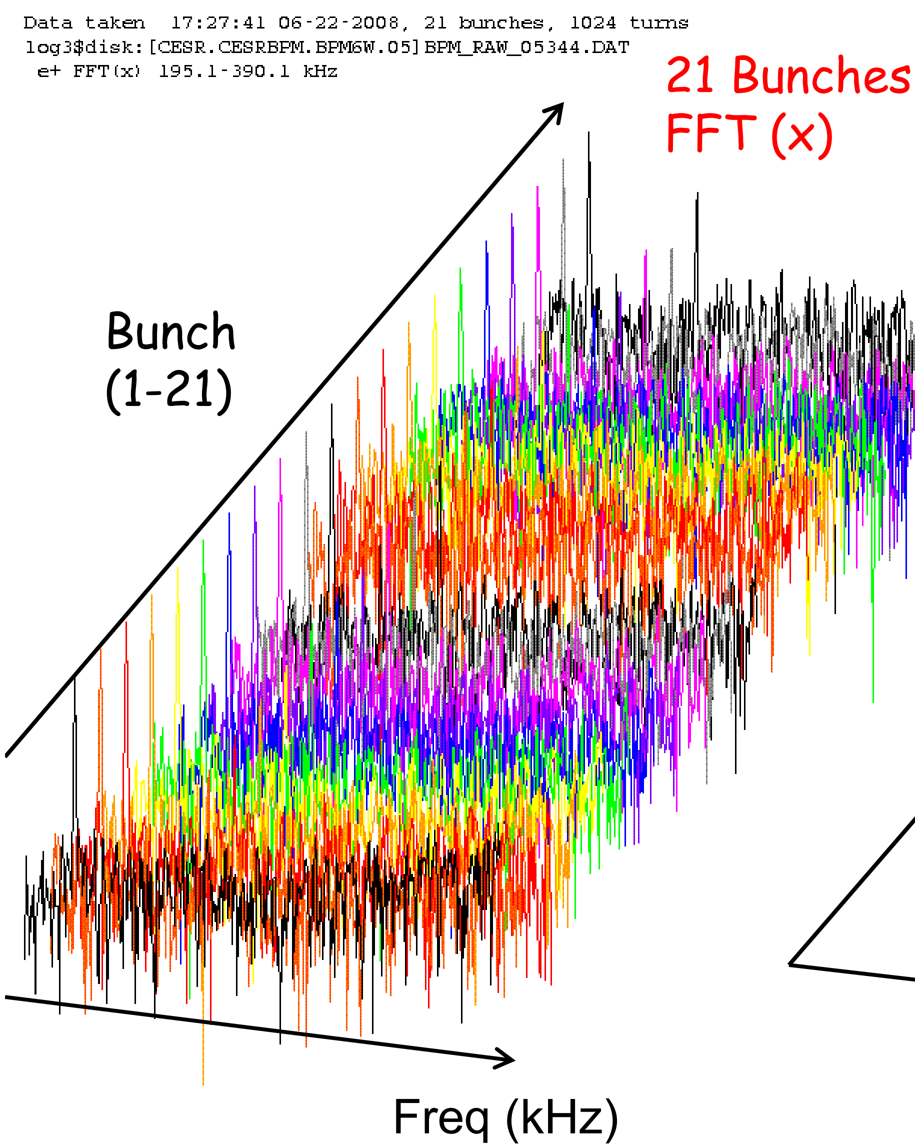
CESR Reconfiguration

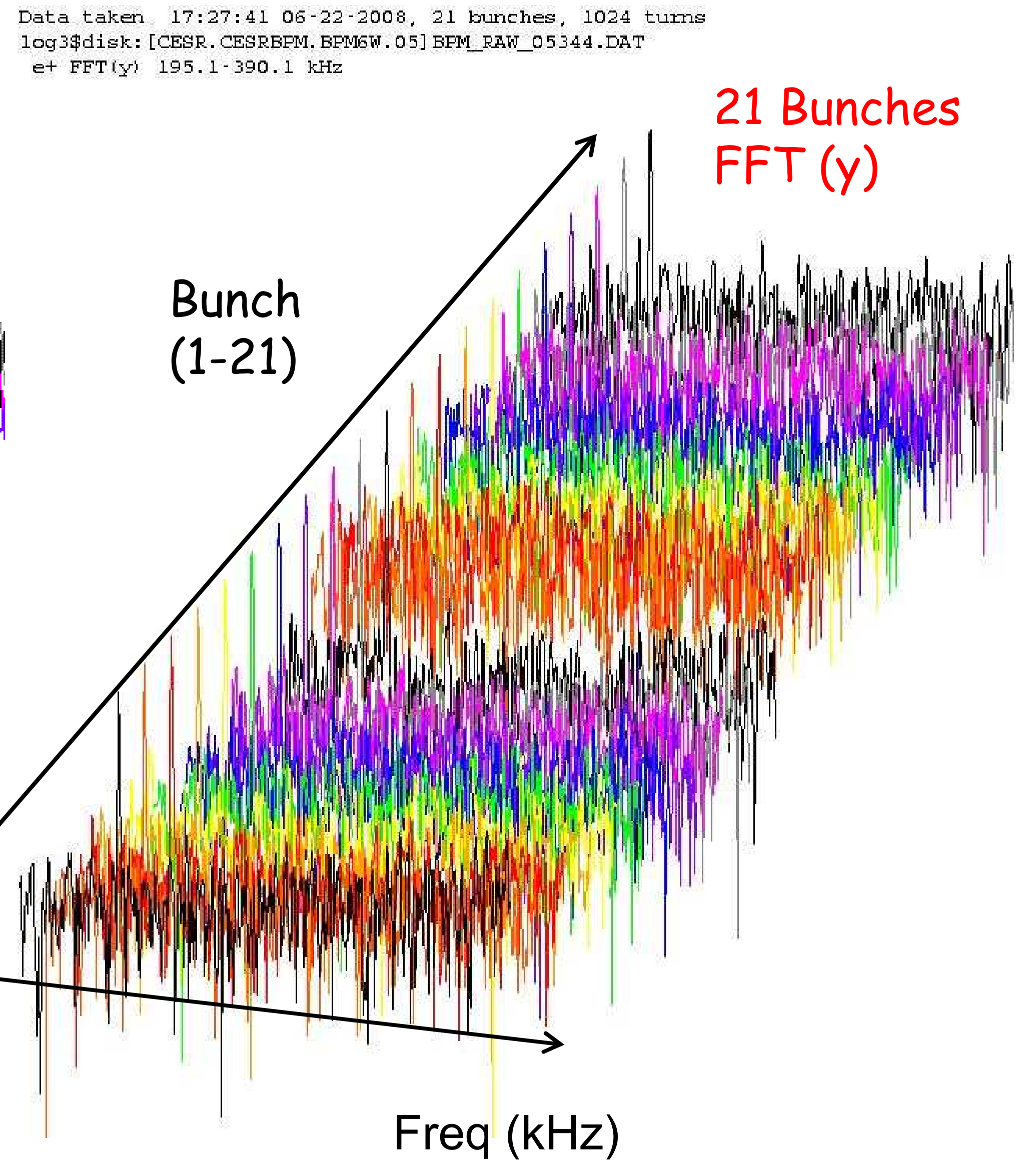
- L3 Straight
  - Instrument large bore quadrupoles and adjacent drifts
  - Install of PEP-II experimental hardware (including chicane) in early 2009
  - Provide location for installation of test chambers
- Arcs where wigglers removed
  - Instrument dipoles and adjacent drifts
  - Provide locations for installation of test chambers
- CHESS line upgrades for x-ray beam size monitor
  - D-line this summer
  - C-line next year
- L0 Straight
  - All wigglers in zero dispersion regions for low emittance
  - Instrumented wiggler straight and adjacent sections



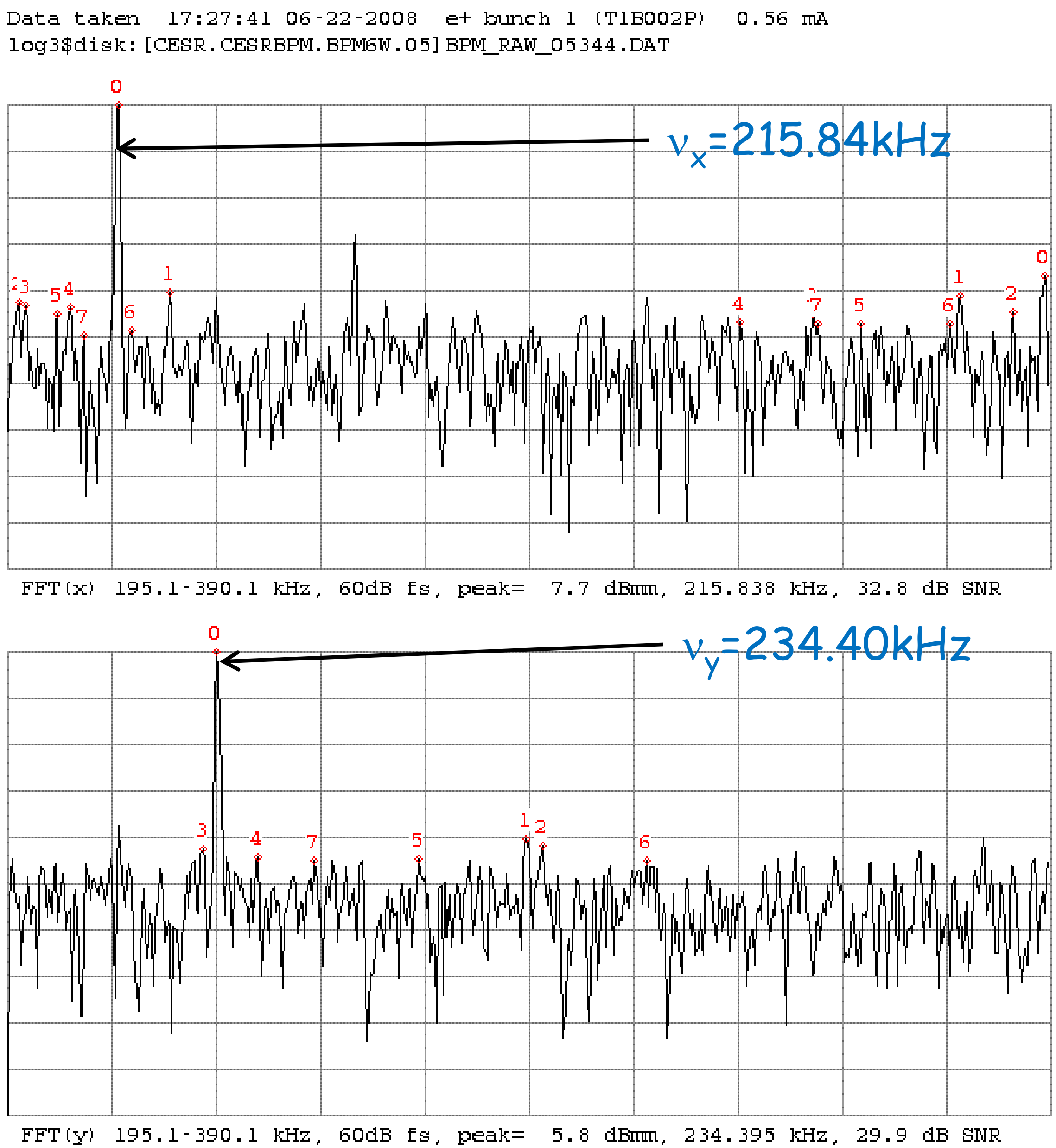
Witness Bunch Experimental Studies at CESR-TA

Robert Holtzapple
Alfred University/Cal Poly San Luis Obispo





- Fast Fourier Transform the vertical/horizontal position to determine the oscillation frequency of each bunch.



Frequency spectrum of bunch 1 in the 21 bunch train.

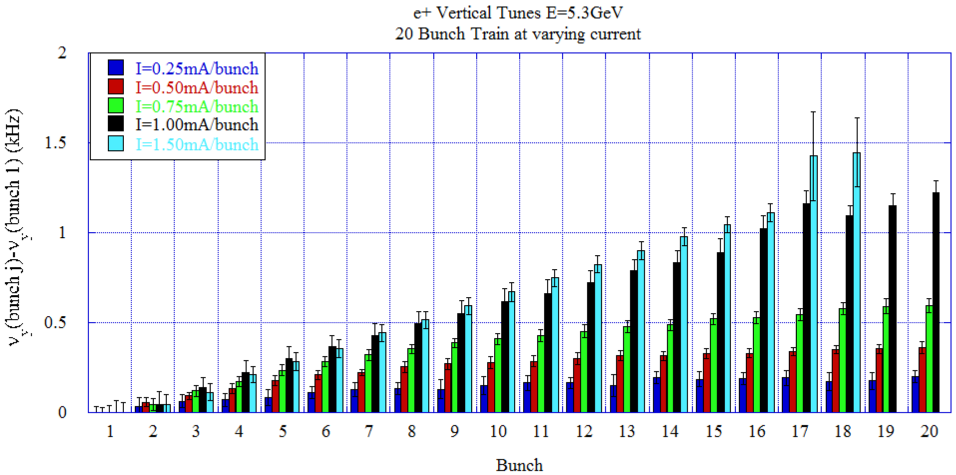
Horizontal spectra

Vertical spectra

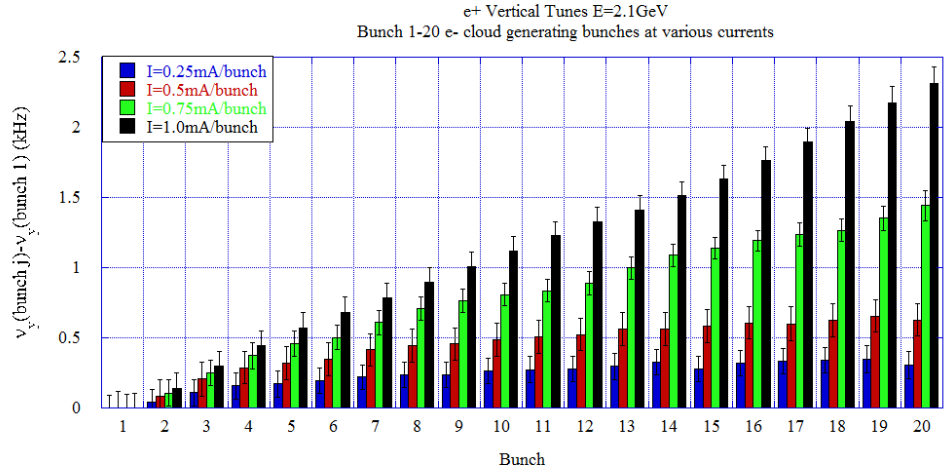
Peak in frequency spectrum is determined in both horizontal and vertical spectra for each bunch.

IV. Witness bunch experiments: Tune shift along 20 bunch train with vary bunch current

e+ E_{beam}=5.3GeV

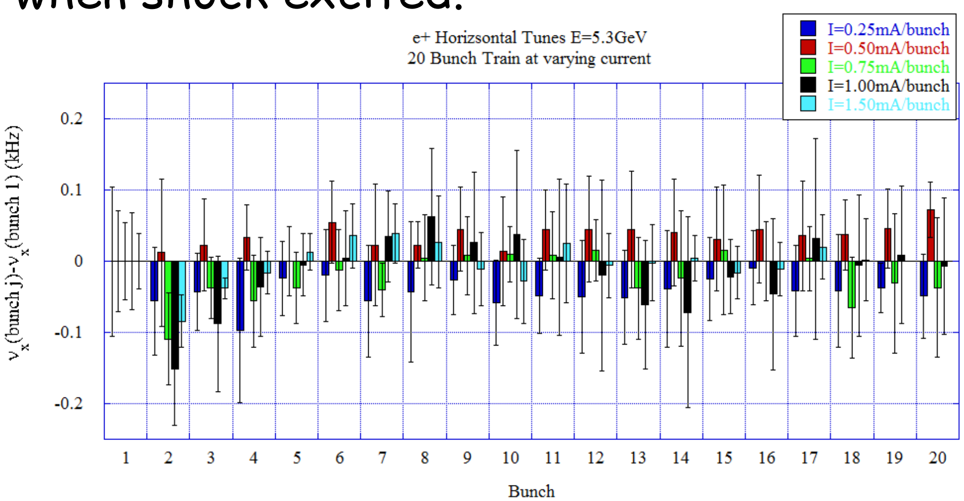


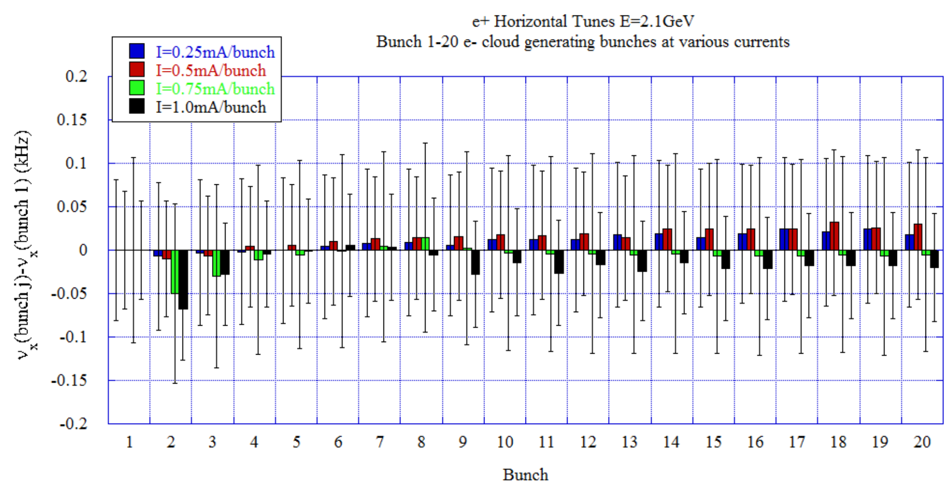
e+ E_{beam}=2.1GeV



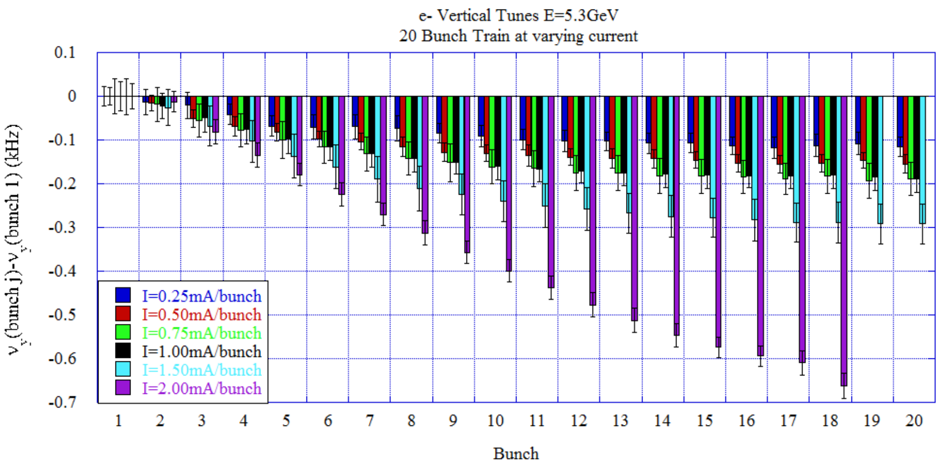
- $\Delta\nu_y$~1.3kHz@1mA/bunch-possible saturation @1.5mA/bunch.
- $\Delta\nu_x$~0.
- lost bunches 19-20@1.5mA/bunch when shock excited.

- $\Delta\nu_y$~2.4kHz@1mA/bunch, no tune shift saturation.
- $\Delta\nu_x$~0.

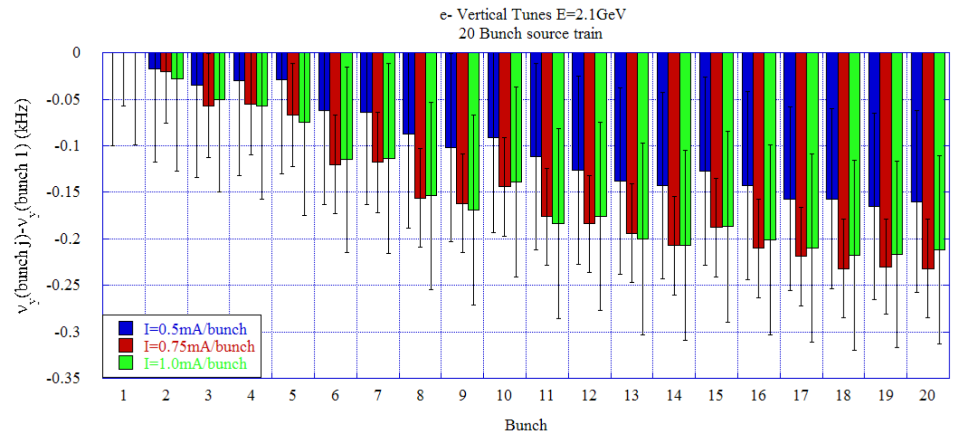




e- E_{beam}=5.3GeV

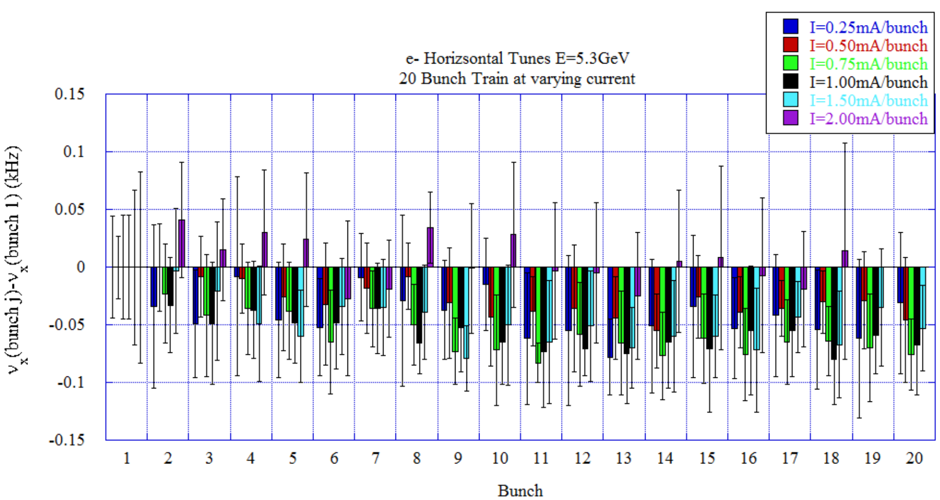


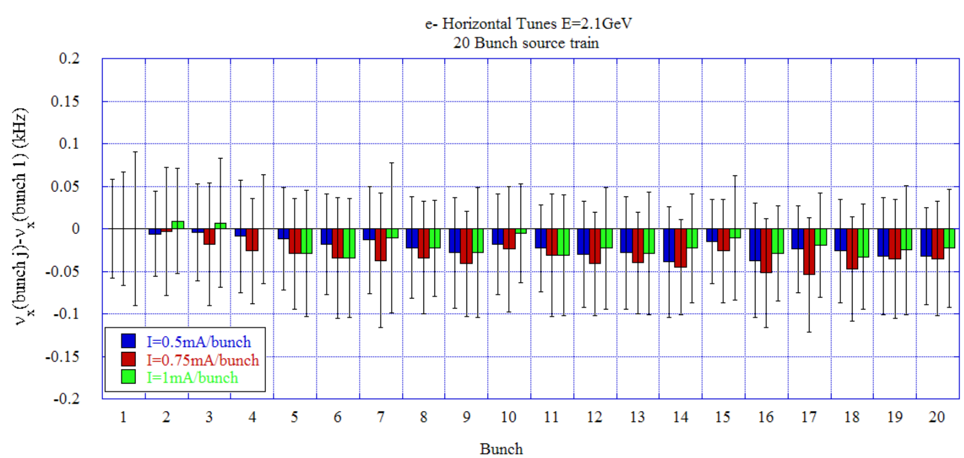
e- E_{beam}=2.1GeV



- $\Delta\nu_y$~-0.2kHz@1mA/bunch
- $\Delta\nu_x$~0.
- lost bunches 19-20@2mA/bunch when shock excited.
- large $\Delta\nu_y$ between 1.5 to 2mA/bunch

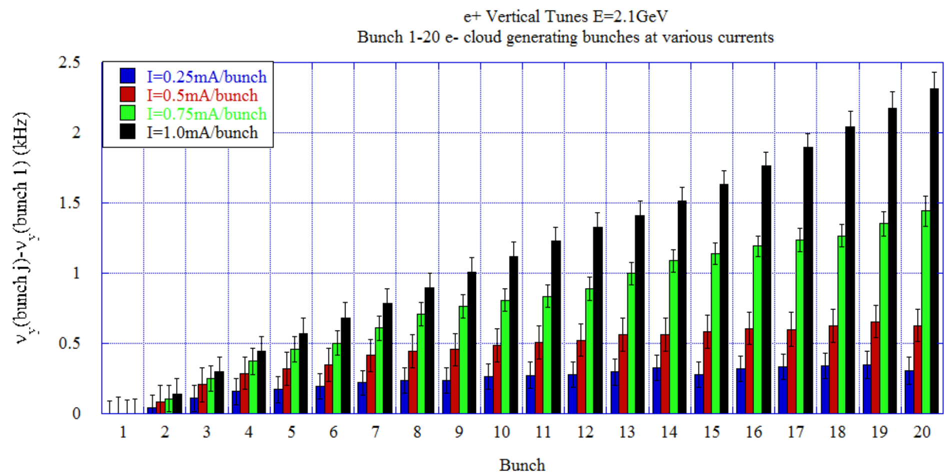
- $\Delta\nu_y$~-0.2kHz@1mA/bunch, similar to high energy tune shift. No significant change in tune shift with current.
- $\Delta\nu_x$~0.

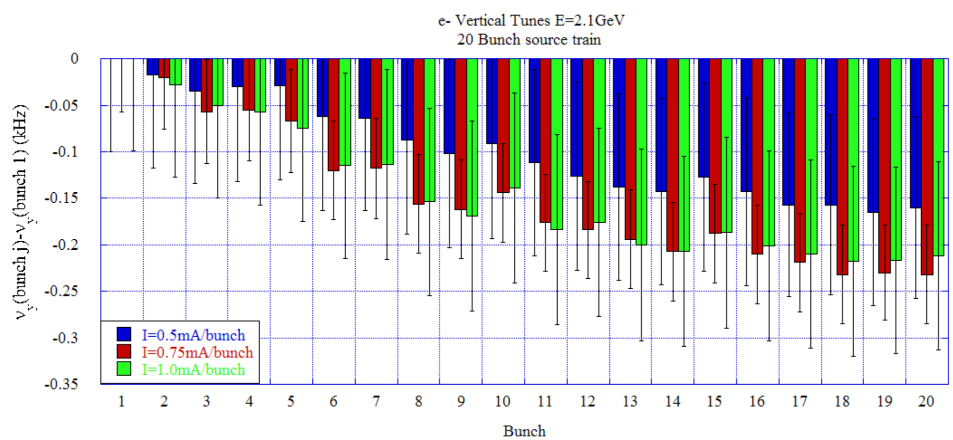




Comments on Applicability to Protons

- Tan and I participated in some of these studies – so we had time to think about them
- Tune Shift grows linearly, then turns over
    - For MI we expect exponential growth, then turnover
- Tune shift is present for electrons and positrons with different signs
- Conclusion: photo – not secondary – electrons are producing the cloud
- Comparison between machines will be rather difficult
    - Tuning may not be valid
- Simulators have focused on their models of secondary emission, while photo-emission is probably more important for these machines





Cornell University
Laboratory for Elementary-Particle Physics

Electron Cloud Simulations at Cornell for Cesr-TA, and comments on tune shift-density relationship

ILCDR08 - July 9, 2009

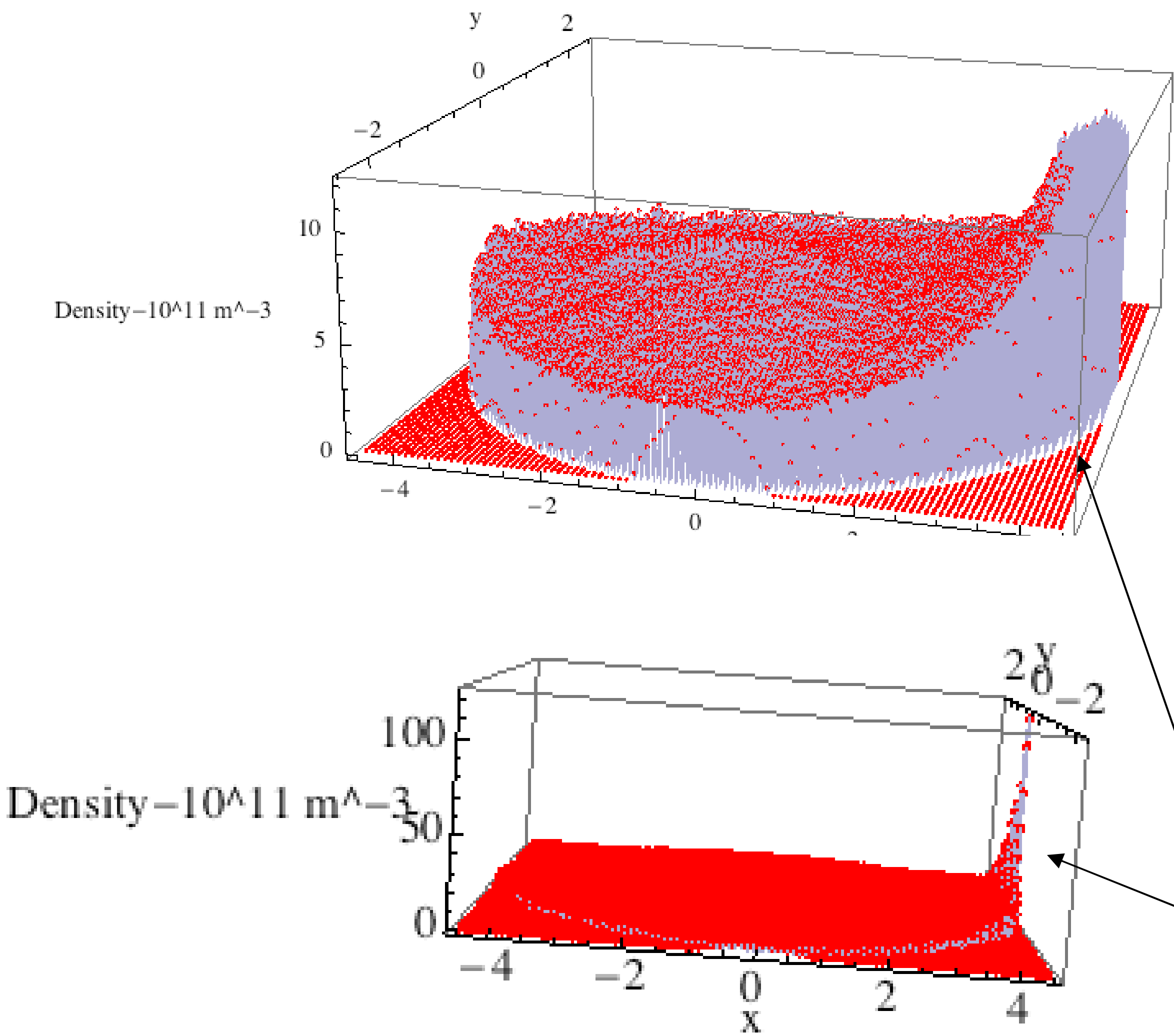
G. Dugan

Cornell Laboratory for

Accelerator-Based Sciences and Education

Numerical example-density distribution from a simulation

Elliptical chamber H (x) x V(y) axes=4.45 x 2.45 cm



POSINST
Cesr-TA typical drift region
Time-averaged density

Photoelectron spike

Distribution of Electrons

- The coherent tune shift observed at Cesr is strong in vertical, small in horizontal
- This is entirely due to most of the electrons being at the outside wall of the chamber
- For the MI (or any proton machine), we expect a much more symmetric and more uniform distribution
  - Not completely uniform, just moreso
- It will be interesting to do a similar study in MI, but we shouldn't expect similar results

Simulation codes

G. Dugan

- We will be using three simulation codes at Cornell: ECLOUD, POSINST, and CLOUDLAND.
- We are in the process of running these codes for the same set of simulation parameters, representing typical CesrTA conditions, including weighting with radiation intensity, in dipole and drift, and local conditions at RFA probe locations.
- Input and output files for each program will be posted on the CesrTA Cloud Simulation web page for reference.
- At the same time, we are using to results of the simulations to help understand the witness bunch tune shifts measurements, and the RFA data.

Simulations

- Paul et al. are developing Synergia
- Leonid may be able to adapt ORBIT to MI
- Cornell is building a simulation mill using other codes
  - POSINST, ECLOUD, CLOUDLAND
- We will hopefully be able to learn from their experience and set up a mill that could compare to in-house work
  - This may be a priority, but we don't have anyone to work on it now

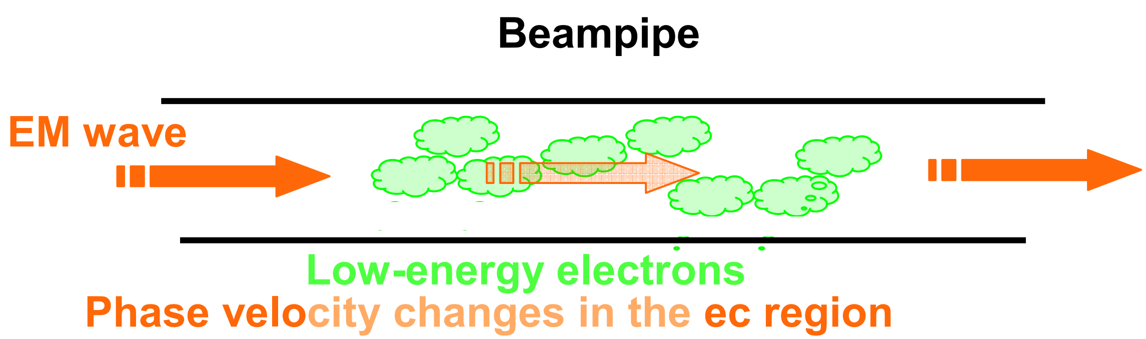
Measuring Electron Cloud Density at CesrTA by Microwave Transmission

J. Byrd, M. Billing, S. De Santis, M. Palmer, J. Sikora

ILC Damping Ring R&D Workshop 2008

July 9th, 2008

Measurement by microwave transmission



Propagation through the electron plasma introduces an additional term to the standard waveguide dispersion:

$$k^2 = \frac{\omega^2 - \omega_c^2 - \omega_p^2}{c^2}$$

Plasma frequency
$2c(\pi \rho_e r_e)^{1/2}$

Beampipe cut-off frequency

The presence of the “electron plasma” affects the propagation of the wave, while there is essentially no interaction with the ultrarelativistic beam.

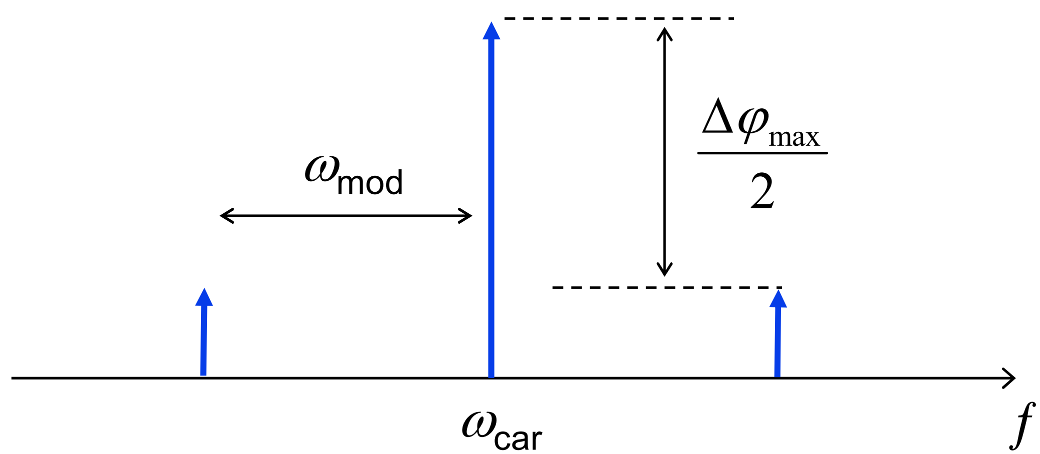
Phase Modulation

The *periodic clearing of the electron cloud* by the gap, when it passes between our Tx and Rx BPM's *phase modulates the transmitted signal*:

$$s(t) = A\cos[\omega_{car}t + \Delta\varphi(t)]$$

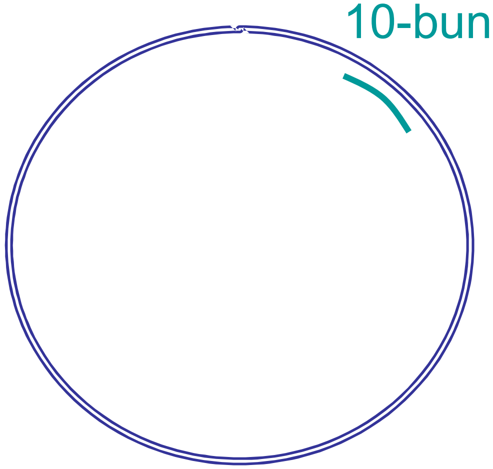
- What happens if the gap is not long enough to completely clear the electrons ?
- What happens if the gap is shorter than the distance between Tx and Rx ?

If $\Delta\varphi(t) = \Delta\varphi_{\max}\sin(\omega_{\mathrm{mod}}t)$



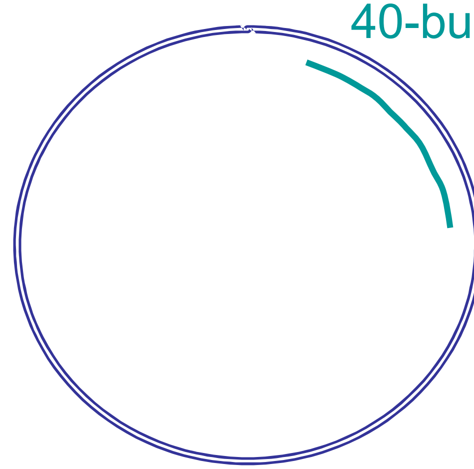
CesrTA Fill Patterns (e^+/e^-)

10-bunch train

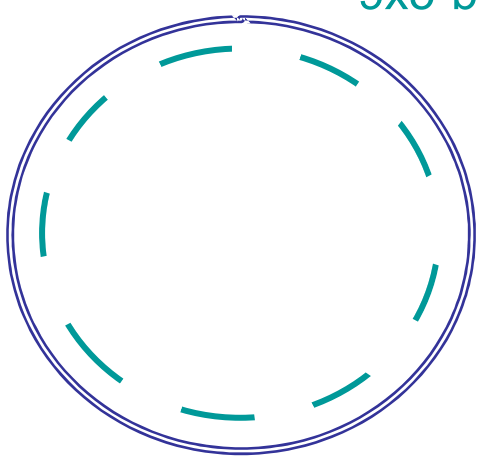


Energy = 2 - 5.2 GeV
Gap length ≈ 210 ns - 2.4 μs
Revolution frequency ≈ 390 kHz
Bunch spacing ≈ 14 ns

40-bunch train



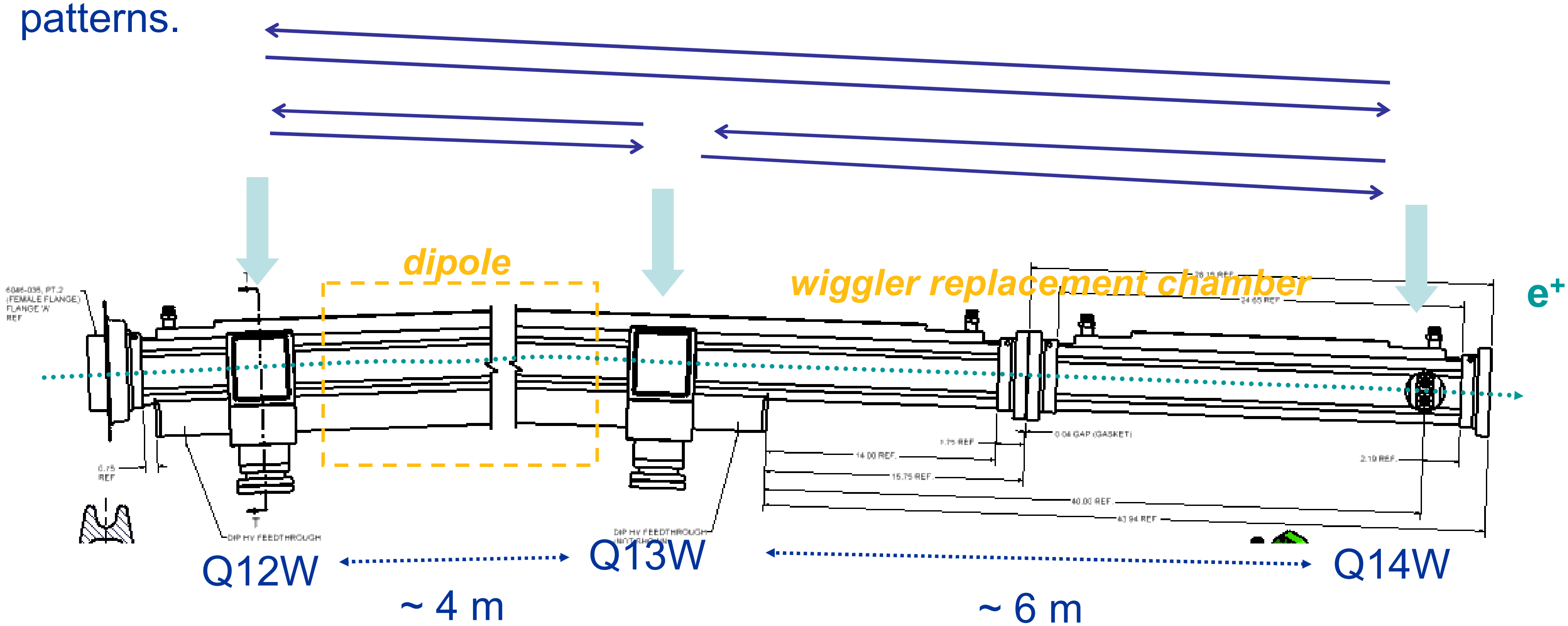
9x5-bunch trains



in this case the gap revolution frequency is 9 x f_{rev}

Transmitter/Receiver Positions

We had 3 BPM available for the measurement, to be used either as transmitting or receiving port.
By trying all the possible combination, we were able to test the effects of different vacuum chambers, different propagation lengths, and different propagation direction between e^+ or e^- beam and TE wave.
The measurements were taken at both 2.0 and 5.2 GeV, with a variety of fill patterns.

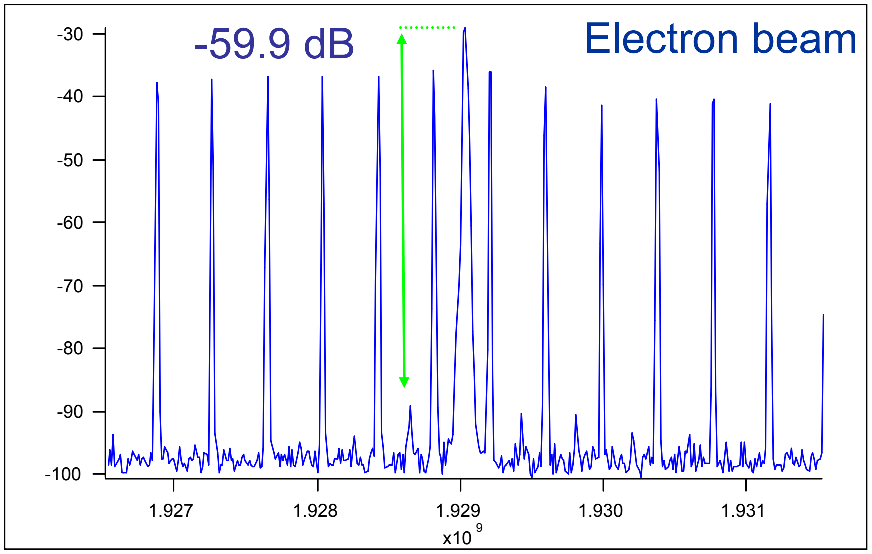


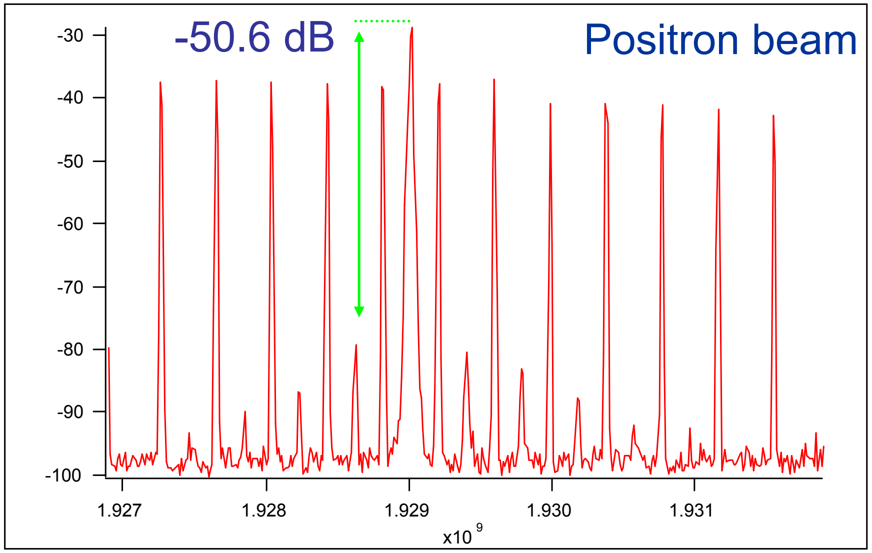
Electron vs. Positron Beam

2 GeV - Dipole region (Q12W-Q13W) 10 bunches x 1 mA

Difference in the relative sideband amplitude between electron and positron beam, in otherwise identical machine conditions.

The low-energy electron density in the presence of a positron beam has a ~3 times higher value than with an electron beam.
This effect is due to the multiplication of secondary electrons caused by resonant interaction of beam and e-cloud.



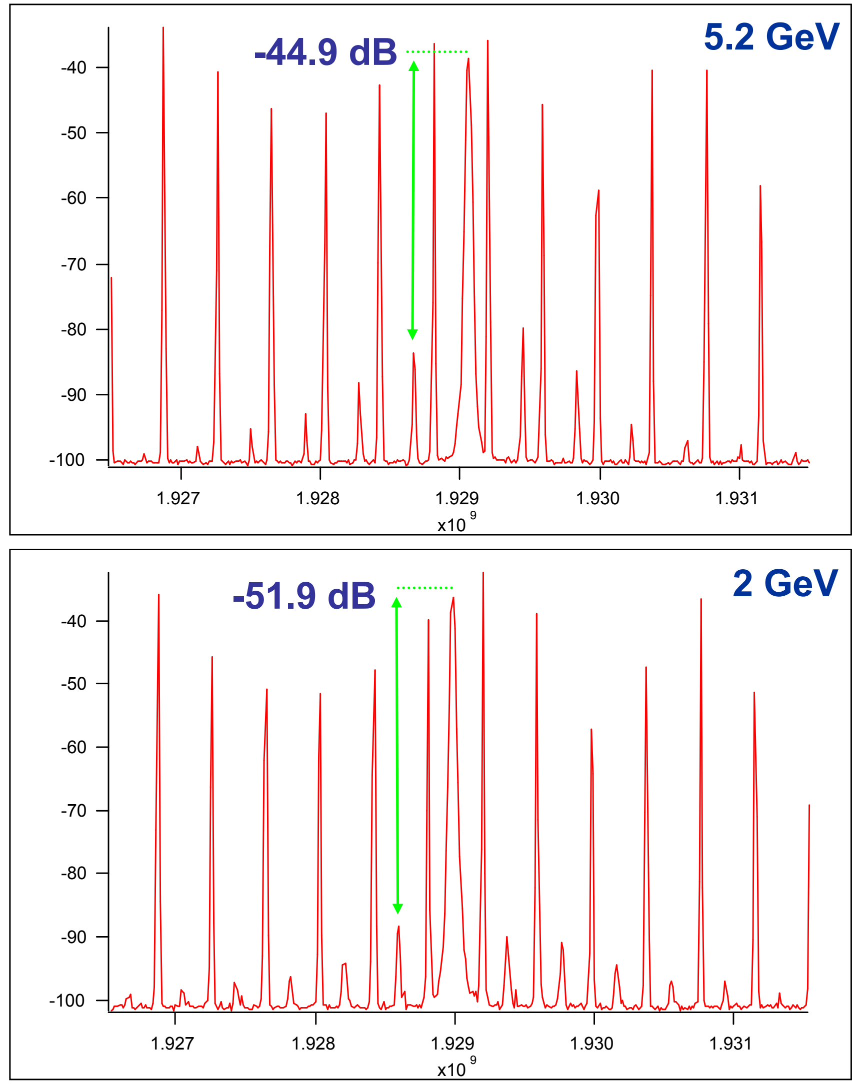


2 Gev vs. 5.2 Gev Measurements

Ex-Wiggler region (Q13W-Q14W) 10 bunches x 1 mA

Difference in the relative sideband amplitude between two different beam energies (positron beam).

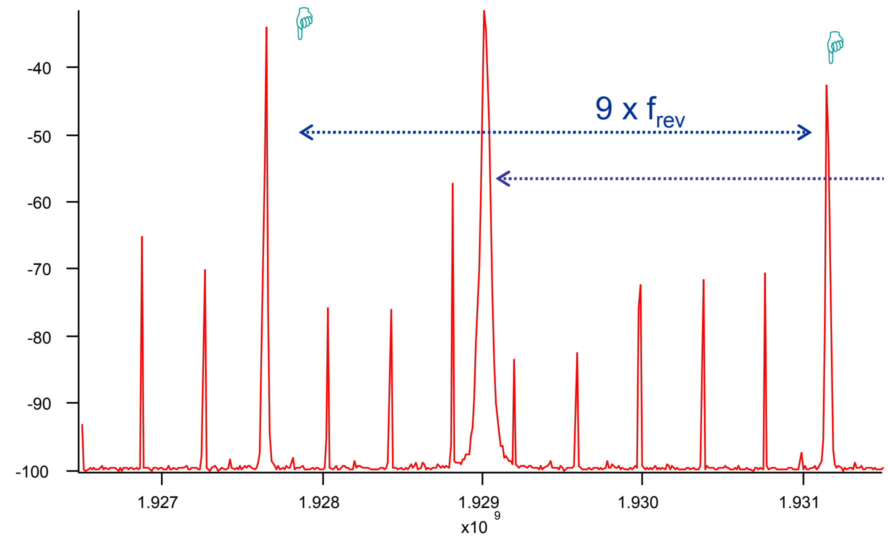
At higher beam energy the enhanced production of photoelectrons increase the low-energy electron density by a factor greater than 2.

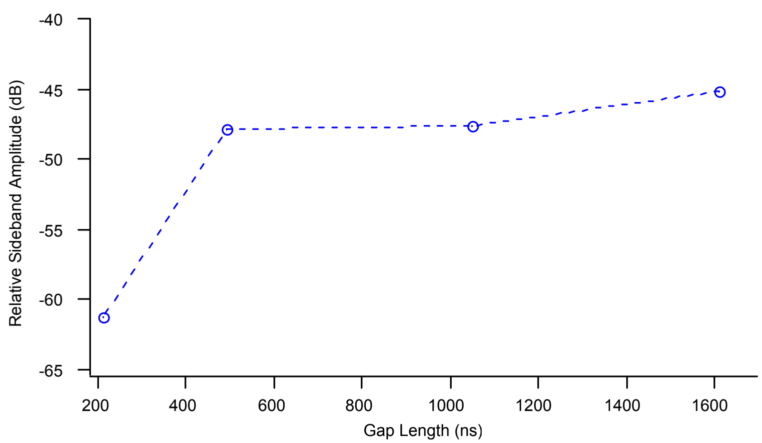


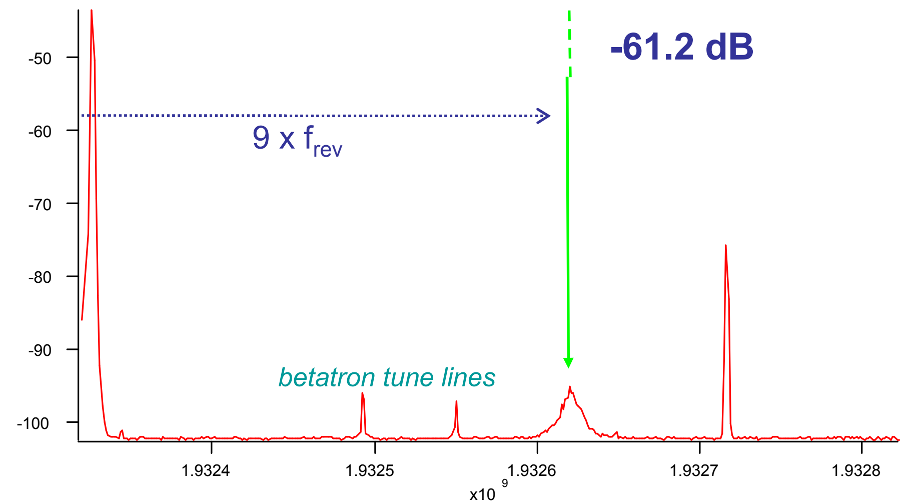
9 x 5 Bunch Fill Pattern

Ex-Wiggler region (Q14W-Q13W) 45 bunches x 1 mA

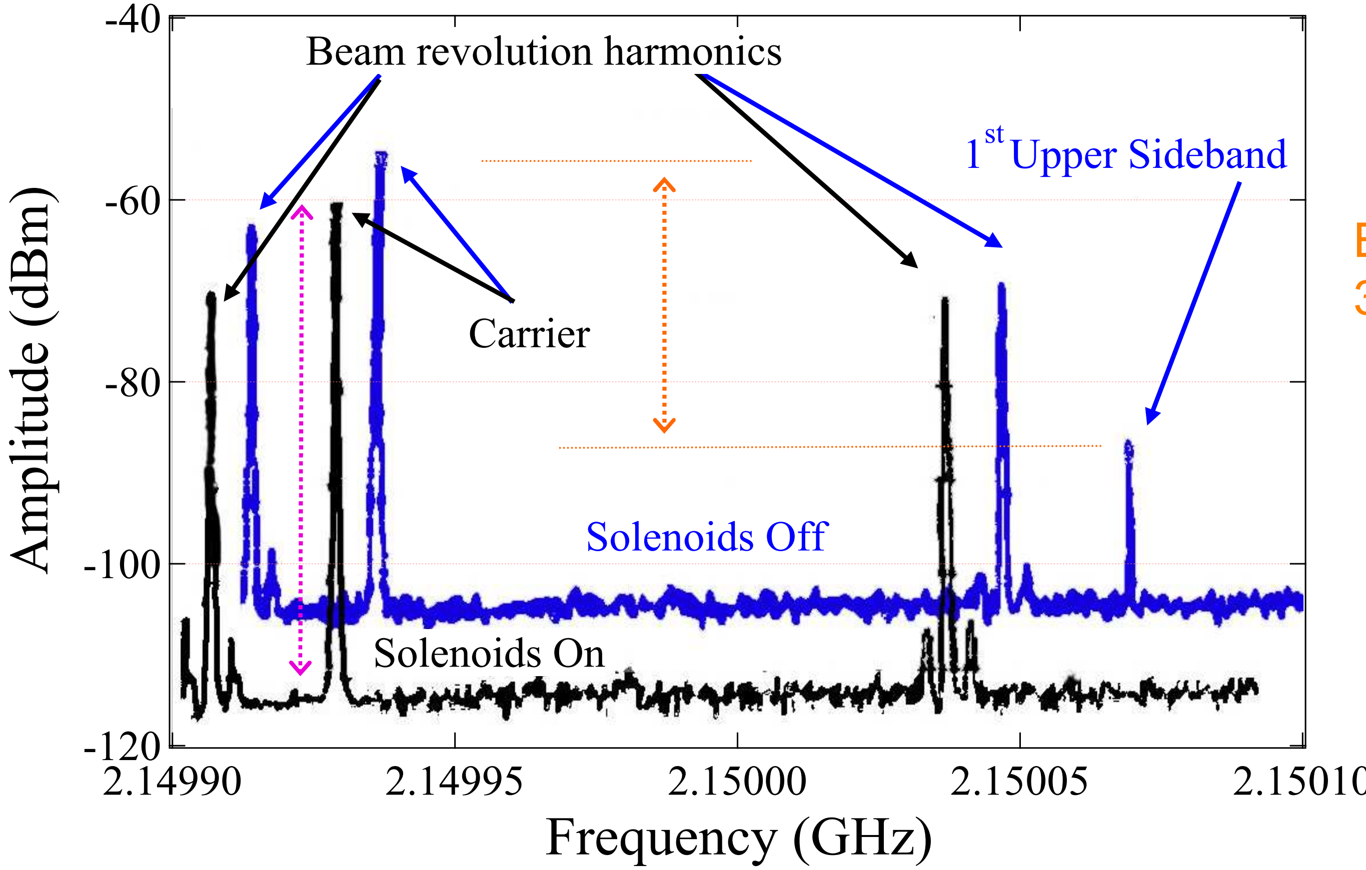
Effects of the bunch periodicity are evident (enhancement of the ninth revolution harmonic ☟). Although total current is higher (45 vs. 10 mA). The much shorter gap (210 ns) induces a much smaller modulation depth. The ninth sideband is also enhanced.







Clearing Solenoids (PEP-II)

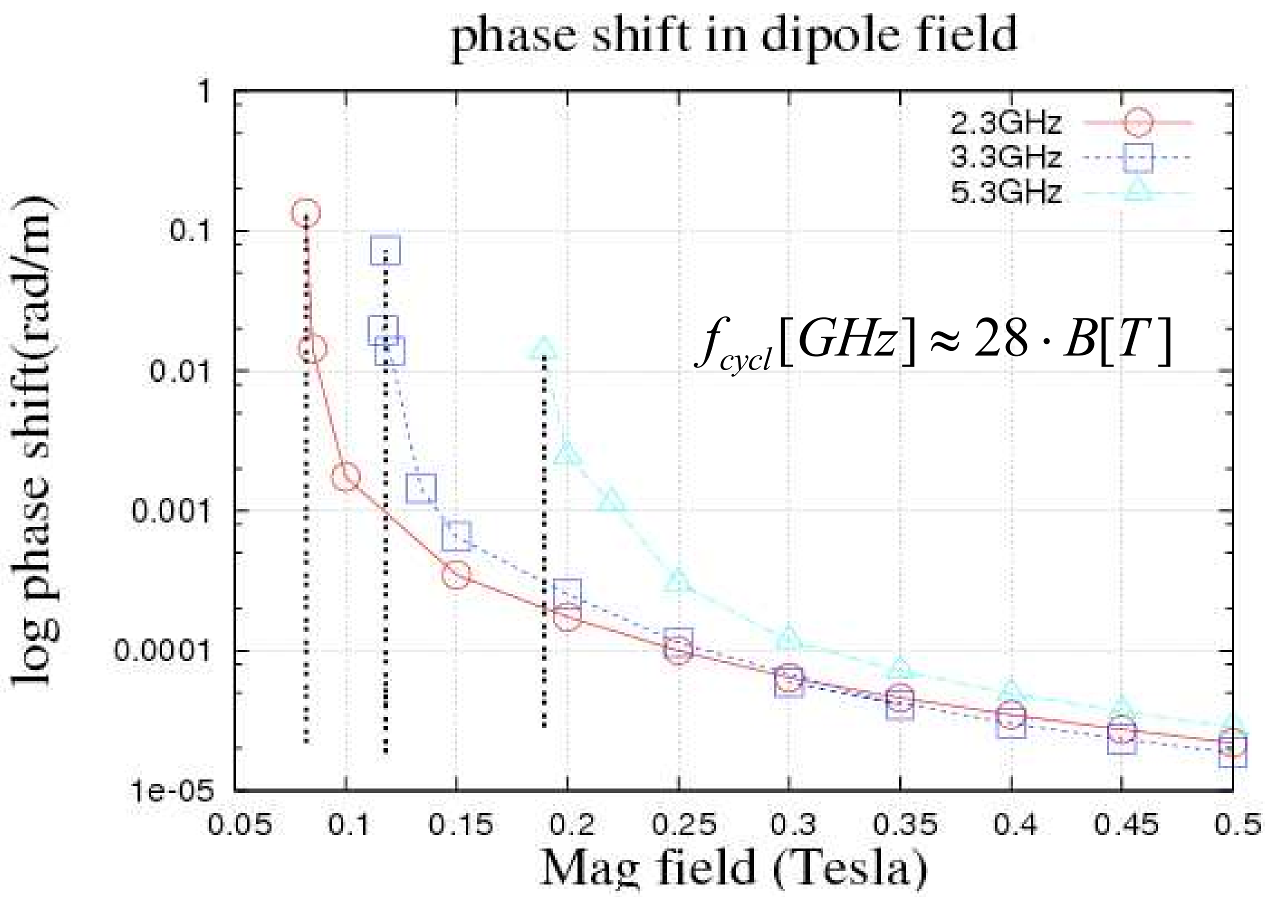


SNR: 50 dB

ECD resolution: $3 \cdot 10^{10}$ e^-/m^3

Although the time evolution of the e-cloud density is not simply sinusoidal, the simple model already gives results in good agreement with other estimates (codes)

Cyclotron Resonance

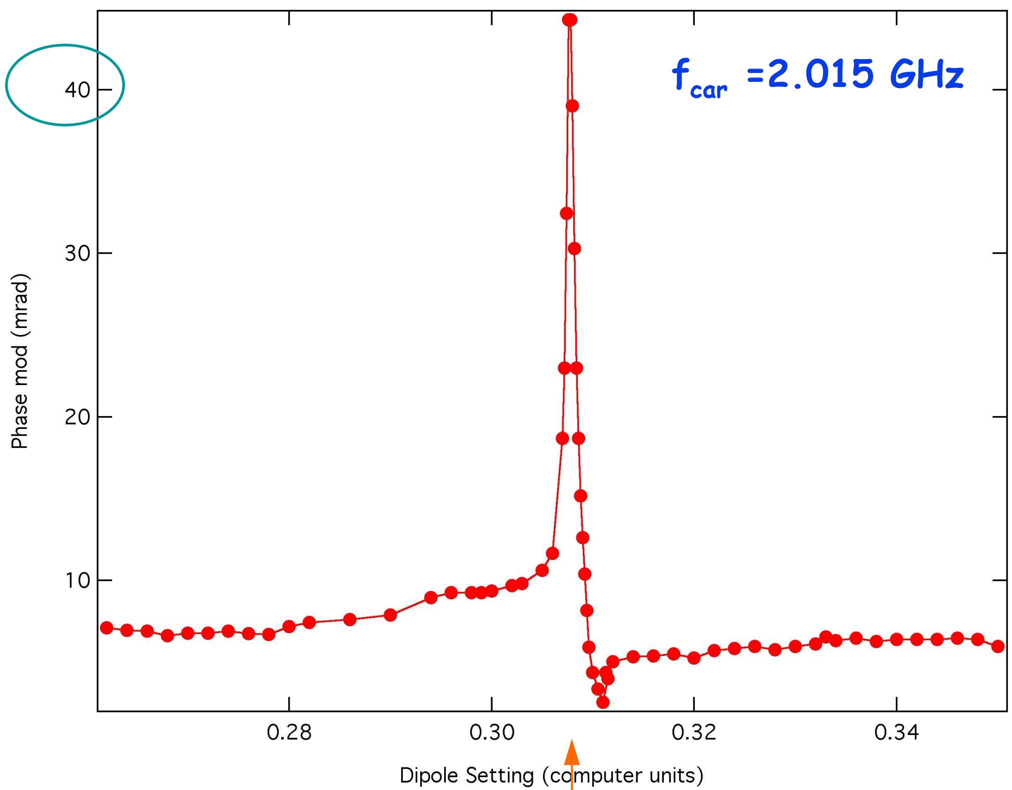


But what is the relationship between this phase shift and the e-cloud density ?
Are we measuring the ECD, or rather the magnetic field strength ?

Cyclotron Resonance Measurement

Unequivocal measurement of a cyclotron resonance

40+ mrad over a length of only 4 meters !



B≈700 G (~1.96 GHz)

Comments on Microwave Transmission

- Very interesting results
- Have several smoking guns:
  - 9x revolution frequency modulation
  - Clearing solenoid effects
- Can see significant effect over short regions of both dipole are drift
- See very large phase shift in dipole corresponding to an electron cyclotron resonance

- Even without full simulation/theory support, we should try this as an ECloud diagnostic

Electron Cloud Mitigation R&D at SLAC

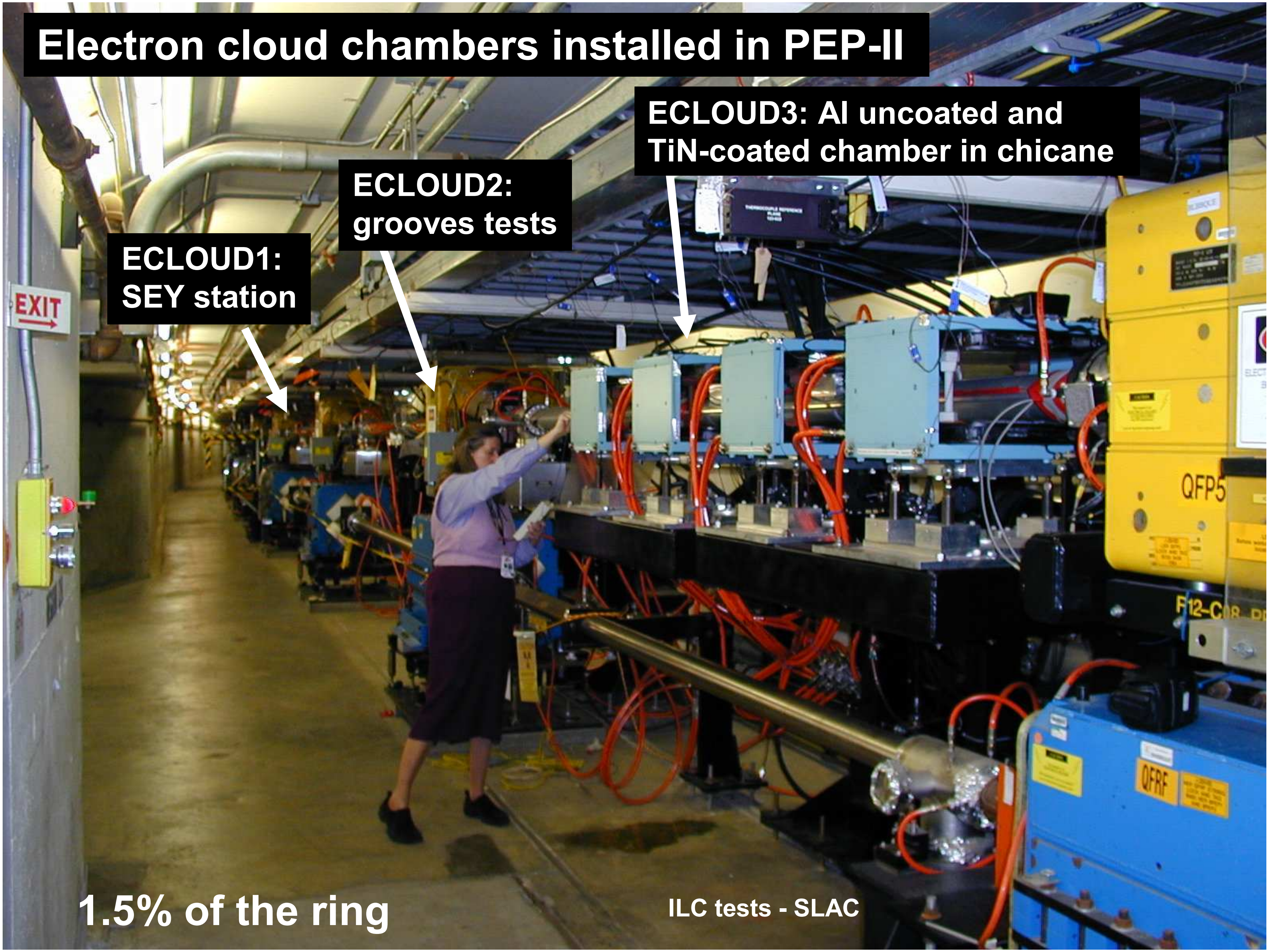
M. Pivi, D. Arnett, G. Collet, T. Markiewicz, D. Kharakh, R. Kirby, J. Seeman, L. Wang, T. Raubenheimer (SLAC)

ILC Damping Ring - ILCDR08

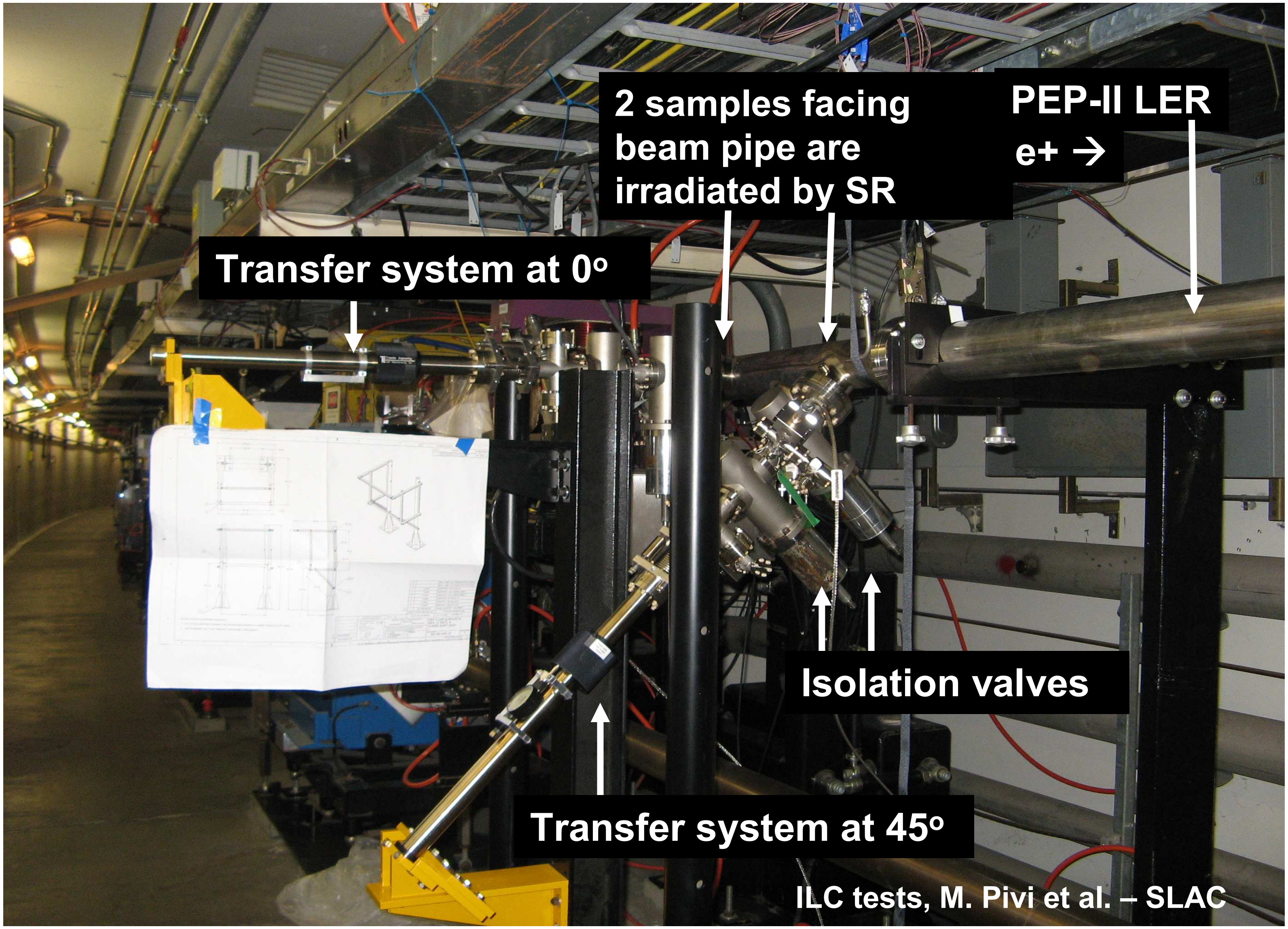
Cornell University

8 to 11 July 2008

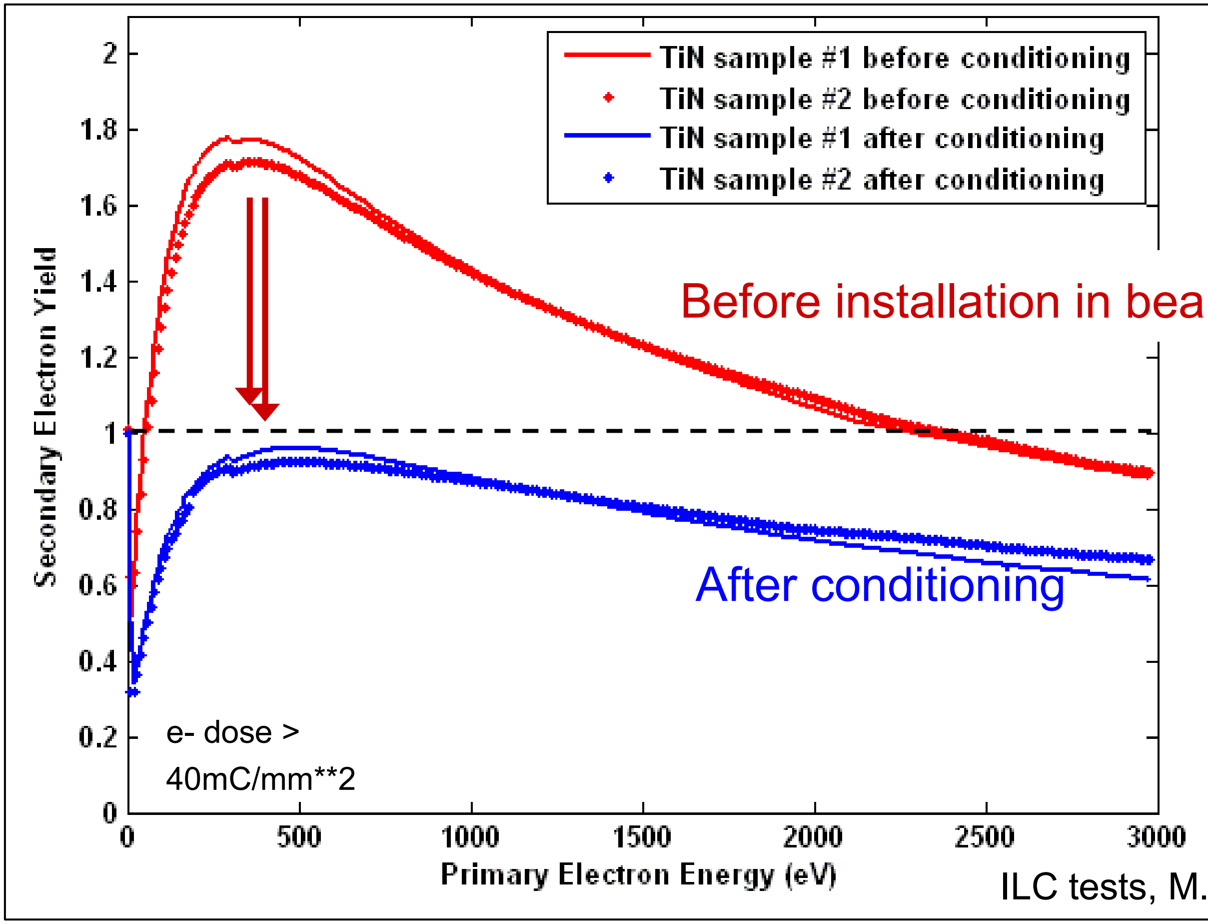
Electron cloud chambers installed in PEP-II



"ECLOUD1" SEY test station in PEP-II



Results of Conditioning in PEP-II LER beam line



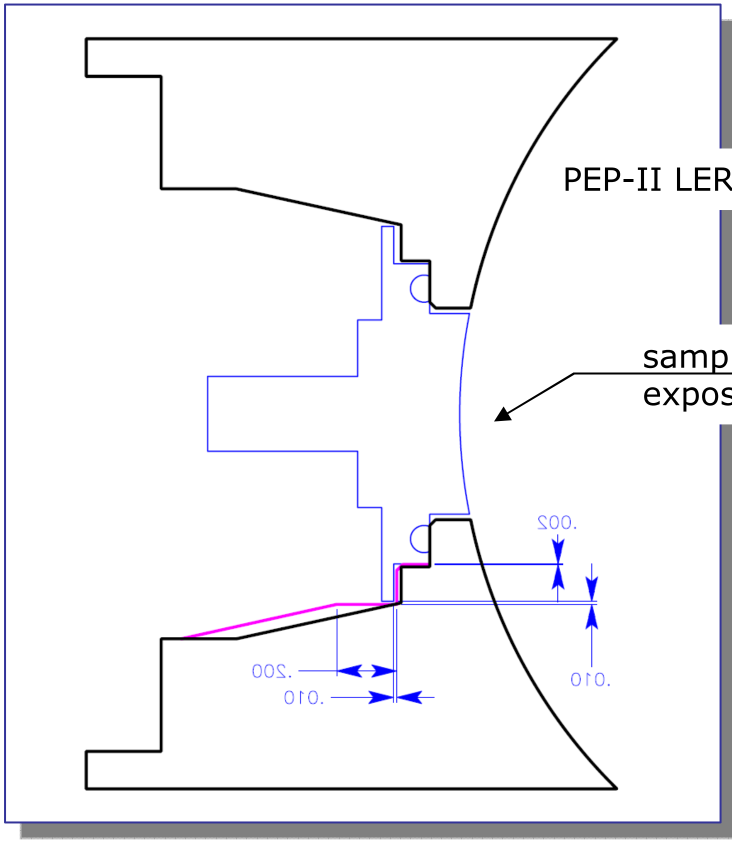
ILC tests, M. Pivi et al. – SLAC

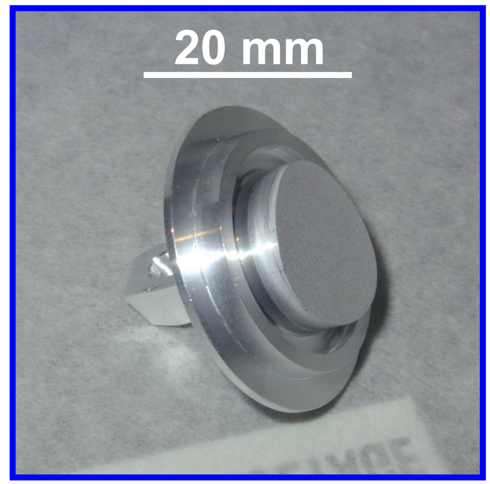
Tin samples measured before and after 2-months conditioning in the beam line. Samples inserted respectively in the plane of the synchrotron radiation fan (0º position) and out (45º).

Similar SEY measured *in situ* at KEKB by S. Kato et al.

SEY TESTS TiN and NEG

Expose samples to PEP-II LER synchrotron radiation and electron conditioning.
Then, measure Secondary Electron Yield (SEY) in laboratory.
Samples transferred under vacuum.





Complementary to CERN and KEK studies

Summary ECLOUD1 experiment

Summary of samples conditioned in the accelerator beam line

	SEY before installation	SEY after conditioning
TiN/Al	1.7	0.95
TiZrV	1.33	1.05
Al	3.5	2.4
StSt	1.85	1.26
Cu	1.8	1.22

ECLOUD1 Plans

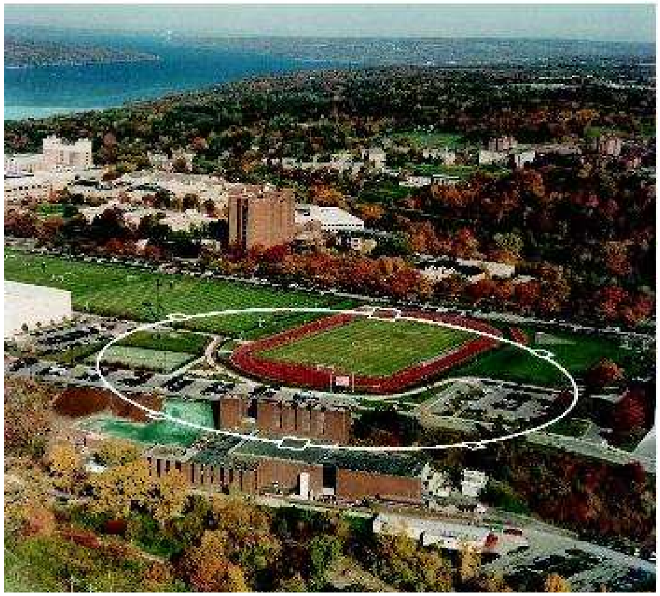
- We will collaborate with Cornell to install this in CesrTA
  - At the same time, we will help build the external SEY test station
- After ~ 1.5 yrs, Cornell will send ECLOUD1 to us for installation into MI
- We hope to test several materials of interest, including stainless, and TiN coated stainless

CesrTA Electron Cloud Mitigation Plans

Mark Palmer

Cornell Laboratory for

Accelerator-Based Sciences and Education



L3 Capabilities

- By mid-2009:
  - PEP-II Chicane with single slot for swapping in test chambers
    - Will complete and test grooved chamber which could not be tested in PEP-II
  - Drift region test chamber slot(s)
    - Available for collaborator and local use
    - Provides relatively low direct synchrotron radiation load

      ~0.025 photons/beam particle/meter @2GeV

      ~0.065 photons/beam particle/meter @5.3GeV
  - Present bi-directional synchrotron light mirror at L3 center to be replaced by 2 *retractable* mirrors at either end of section (just inside Q48s)
    - *Retractable mirrors will allow controlled masking of synchrotron radiation stripe for either beam*
  - Ready for deployment of large bore quadrupole test chambers

ECLOUD3

- Bigger SLAC Test station at CesrTA
- Includes 4 dipole chicane
  - RFAs in drift and in dipole
  - Possibilities for test chamebrs (coatings)
- Allows testing of ECloud build-up in arbitrary magnetic field
- After CesrTA, there are no present plans for ECLOUD3
  - We should decide if it would be useful here